*EIMER'S EVOLUTION OF BUTTERFLIES.**

The criticism, by Professor Minot, of the second part of Eimer's work, '*Artbildung und Verwandtschaft bei den Schmetterlingen*,' which appeared in Science at the beginning of last year (January 3, 1896, Vol. III., No. 53), gives me occasion to again explain Eimer's evolutionary theory, which, so far as I can see from Minot's article, has in many respects been misunderstood. It seems as though Minot were not well acquainted with Eimer's earlier works on the markings of animals, works in which questions of evolution were already discussed. And, as Eimer's present views on this subject are chiefly founded on the results of these earlier works, it is easy to understand why many assertions which need these results for their proof, seem incomprehensible to Minot. Minot calls Eimer 'an enthusiastic opponent of Darwin's theory of natural selection.' It is true that through his investigations on the markings of different groups of animals Eimer became more and more confirmed in his opinion that natural selection was of no moment for the origin of species. This view is expressed in the 'Butterflies,' with the distinct reservation (see p. 68) that he acknowledges the efficiency of natural selection in preserving and intensifying such characters as have previously been developed by other agencies to such an extent as to become useful to the organism in question. Eimer, then, occupies the same position that Mivart defended against Darwin (see 'Origin of Species', Germ. ed., 1876, p. 249 ff.) and he is a decided opponent of the teleological views spread by some of Darwin's followers rather than by the latter himself.

According to Eimer species originate by organic growth, a term first defined by him in his 'Origin of Species.' In the constitutional changes which organisms undergo during life in consequence of external influences, such as climate, food, etc., he sees the first agents that cause the development of new characters. These changes first reveal themselves as growth-phenomena. It is the struggle for existence that gives rise to selection from among these changes, that rejects or adopts. I must consider it a misrepresentation to call this view of the origin of species a bold hypothesis. It is merely the result of investigations which prove plainly that, in the more sensitive representatives of a species, external influences can and do produce individual variations, and that we find these as aberrations in contiguous districts and as species in those that are more distant. Eimer first mentions this thesis in his work on '*Das Variiren der Mauereidechse*'* and makes it probable by his observations; more striking proofs, however, are given in his work on the 'Evolution of Butterflies.' Our native horadimorph butterflies, such as *Vanessa levana* and *V. prorsa*, *Pieris bryoniae* and *napi*, make it sufficiently obvious that external influences are no indifferent factors in the formation of organisms. A variation of temperature to which the chrysalis is exposed produces, from the eggs of one and the same species, butterflies which differ so much in their external structure that for a long time they were held to be separate species. Dorfmeister† and Weismann‡

* Die Artbildung und Verwandtschaft bei den Schmetterlingen, II. Teil., von Dr. G. H. Th. Eimer, und Dr. C. Fickert. Jena, G. Fischer, 1895.

* Eimer: Untersuchungen über das Variiren der Mauereidechse, ein Beitrag zur Theorie von der Entstehung aus konstitutionellen Ursachen. Archiv. f. Naturgeschichte (und selbständig). Berlin, Nicolai, 1881.

† Dorfmeister: Über die Einwirkung verschiedener während der Entwicklungsperioden angewendeter Wärmegrade auf die Färbung und Zeichnung der Schmetterlinge. Mitteilungen d. naturw. Vereins für Steiermark, 1864.

‡ A. Weismann: Studien zur Descendenztheorie I. Über den Saisondimorphismus d. Schmetterlinge, 1875.

showed by experiment—they let the chrysalids of the *prorsa* generation develop at low temperature, those of the *levana* at high temperature—that both butterflies belong to one and the same species. Similar experiments have of late been made by Merrifield* and Standfuss† and have revealed still more astonishing phenomena in a great number of butterflies. They all tend to prove that the forms developed in heat or in cold respectively, always possess those qualities which characterize variations and nearly allied species of these butterflies living exclusively in warmer or colder climates. And not only the markings, but also the form of the wings and the whole configuration of the animal change. In his criticism Minot does not so much as mention these facts, which Eimer regards as a proof that the views on which his theory is based are correct; on the contrary, he particularly emphasizes that Eimer's theories are founded only on the study of the markings of animals and the geographical distribution of forms. It is true that, guided by the results of his earlier researches, Eimer regards these markings as the most characteristic signs of affinity between the various species.‡ And he considers as a further proof of the correctness of this assumption the results of the artificial development of butterflies in lower or higher temperatures in their relation to the geographical connection of forms.

Eimer's theory further materially differs from that of Natural Selection in its explanation of liabilities and tendencies to changes.

Natural selection presupposes the most varied liabilities to changes, in order to become efficient in the production of forms; Eimer, on the contrary, is of opinion that individuals can only follow prior determined, *i. e.*, definite tendencies of evolution (not predetermined tendencies, as Minot wrongly understands). This 'Orthogenesis,' in opposition to Nägeli's view, does not always tend towards perfection, but often towards simplification and retrogression. In its rudiments this law shows itself in the markings of animals, inasmuch as the primitive form of longitudinal stripes becomes spots, transverse stripes, and uniformity of color. This rule, which Minot wishes to be 'proved, not proclaimed *ex cathedra*,' is followed, as is shown by Eimer's researches, by the ontogenesis and phylogenesis of reptiles,* birds,† and mammalia. Simroth‡ found this law confirmed in Limaces, I myself in the markings on the shells of marine gastropods.§ Although the physiological cause and, therefore, the necessity of this curious phenomenon has not yet been ascertained, yet, as it repeats itself in so many different groups of animals, it cannot be denied the importance of a fact. Hyatt's ||

* F. Merrifield: Transactions of the Entomolog. Soc. of London, 1893–94.

† Standfuss: Über die Gründe der Variation und Aberration des Falterstadiums bei den Schmetterlingen mit Ausblicken auf die Entstehung der Arten. Leipzig, 1894. The same: Handbuch für Sammler der europäischen Grosschmetterlinge. Zürich, 1891.

‡ Darwin also came to the same conclusion, as he says: "We shall hereafter see, especially in the chapter on Pigeons, that coloured marks are strongly inherited and that they often aid us in discovering the primitive forms of our domestic races." Animals and Plants under Domestication, Vol. I., p. 29, London, 1868.

* Eimer: Zoologische Studien auf Capri II., *Lacerta muralis coerulea.* Leipzig, Engelmann, 1874.

† The same; Die Zeichnung d. Vögel und Säugetiere. Württemb. Naturwiss. Jahreshefte, 1883. The same: Über die Zeichnung der Tiere; Zool. Anzeiger, 1882, 1883, 1884, and in the Zeitschrift Humboldt, 1885–88. The same: Mitteilungen über die Zeichnung der Säugetiere, Schmetterlinge u. Mollusken. Tageblatt der 28. Versammlung deutscher Naturforscher u. Aerzte in Strassburg, 1885, p. 408.

‡ Simroth: Versuch einer Naturgeschichte der deutschen Nacktschnecken und ihrer europäischen Verwandten, Zeitschrift. f. wiss. Zoolog. Bd. XLII.

§ Gräfin von Linden: Die Entwicklung der Skulptur u. der Zeichnung bei den Gehäuseschnecken des Meeres: Zeitschrift f. wiss. Zoologie. Bd. LIX.

|| A. Hyatt: Genesis of the Arietidae. Smithsonian

and Würtenberger's* works and my own investigations of the shells of Molluscs have shown that other morphological characteristics apart from the markings produce regular changes in a definite direction. Taking this into consideration I do not consider it a 'bold hypothesis' on Eimer's part, when he believes he has found a confirmation of his law of markings in the case of butterflies, for "any hypothesis which explains various large and independent classes of facts rises to the rank of a well-grounded theory." (See Darwin, Animals and Plants under Domestic. Vol. I., p. 8, 1868.) In the systematic part of his two volumes on 'Butterflies' Eimer shows how seemingly insignificant variations of the markings from the original form invariably develop into definite characteristics of new aberrations and species, the changes being dependent upon physiological conditions. It can therefore not be asserted that butterflies are subject to the most multifarious liabilities to change. The markings of *Segelfalter* and of Swallow-tails can be reduced to one common scheme, which, as the illustrations show, is most simply represented by the markings of *Papilio Podalirius*. This scheme of markings consists of eleven bands which extend over the wings in a fixed direction parallel to the axes of the body. They are called longitudinal bands and are always connected with certain veins of the wings. These eleven bands can undergo several variations. They can become broader and vanish altogether by means of lateral combination, become shorter in the direction from the abdomen or head, and sometimes quite disappear, or develop into single spots and form a transverse marking by means of dark colored scales which show themselves on the transverse veins of the wings. In this way the *Segelfalter*, as well as the Swallow-tails, develop new forms, which, from showing only slight aberrations from the original form in the beginning of the evolutional series, differ materially from it in the end. The same law which thus determines the evolution of the members of a group also determines that of the groups themselves. Each succeeding one begins its development at a somewhat higher stage than its predecessor. Variations which are an exception in the lower groups become the rule in the higher ones. This is the reason why the representatives of the first groups of the *Segelfalter* "have markings very similar to the original form, while the third group contains butterflies which closely resemble the Swallow-tails."

The primitive Swallow-tails have attained a much higher degree of development than the primitive *Segelfalter*, but still it is not difficult to recognize that, although they are not immediately allied to the *Segelfalter*, yet their development follows the same direction. The Swallow-tails still possess indications of a separation of bands, which in the *Segelfalter* have coalesced. Furthermore, fragments of markings which still occur in forms closely related to the Swallow-tails show that the development of their markings depends on the same conditions as those of the *Segelfalter*. It would lead me too far to describe in detail the directions of evolution which manifest themselves in the various groups. I will only mention that the tendency of the bands to broaden and to coalesce can be traced throughout the entire groups of *Segelfalter* and has produced almost melanotic forms in the group of *Asterias* of the Swallow-tails. Further, the shortening of the bands from abdomen to head is characteristic of both *Segelfalter* and Swallow-tails. In both groups the

Contrb. to Knowledge, 1889. The same: Phylogeny of an Acquired Characteristic. Proceedings of the Amer. Philosoph. Soc., Vol. XXXII., No. 143, 1895.

*Würtenberger: Studien über die Stammesgeschichte der Ammoniten, Leipzig, 1880.

bands become spots and combine into a transverse marking by the agency of dark colored scales on the transverse veins. If we neglect secondary differences of markings in the two groups of *Papilio*, we have to assume that they originated in complete independence of each other—a direct relationship cannot be proved—according to the same definite laws of development.

In entire groups as well as in single species, no matter whether they live in the same or in different districts, the law of a definite direction of evolution is shown in homogenesis, or independent similarity of evolution. As examples, Eimer cites the North American *Turnus* and the south European *Alexanor* (which is also found in Asia Minor), of *Segelfalter* the South American *Agesilaus*, *Protesilaus* and the European *Podalirius*.

The phenomenon of homogenesis is of importance as a proof that it is not geographical distribution in the sense of local separation on which the development of different directions of evolution depends.

This short exposition of the direction of evolution in the genus *Papilio* seems to me to show that it was not arbitrariness on Eimer's part to select *Papilio Podalirius* as the ancestral form of his group of butterflies. He has shown, by his study of the markings of one series of forms, that those of all its members can be reduced to one and the same scheme, and that aberrations from the forms which are nearest to this original scheme of markings vary so as to form transitions to nearly allied species, which again are connected with more distant species, and the conclusions drawn from the study of these phenomena are confirmed by the results of geographical distribution. This being so, I cannot understand how Minot can doubt that Eimer's assertions are correct.

Neither does Minot agree with the explanation of the sudden appearance of a second perfectly dark-colored form of the feminine *Papilio Turnus* by 'development by jumps' (*Halmatogenesis*). This singular form of feminine *Turnus* called *var. Glaucus*, which occurs exceptionally in the North and regularly as a summer generation in the South of the United States, seems not to be connected by any transitions with the normal feminine animal. Minot, however, believes it possible that in former times transitional forms existed. It seems to me a matter of course that a highly developed form like *Papilio Turnus var. Glaucus* has to undergo several variations of markings during the chrysalis stage before it can leave it in its present form. But in comparison with the difference between the variation of another species and its original form, that between *Turnus* and *var. Glaucus* remains just as striking, whether we know that during the chrysalis stage forms of transition temporarily occur or that in former times forms existed which made the transition from the normal feminine *Turnus* to the *var. Glaucus* somewhat more gradual. As it at present appears, *var. Glaucus* is a form produced by *Halmatogenesis*. Eimer's theory necessarily leads to the conviction that qualities produced by external influences are transmitted to the descendants of those who have acquired them, an assumption for which Minot demands proofs. The experiments of Weismann on *Polyommatus phlæas*, which are mentioned in the *Zoologische Jahrbücher*, 1895, *Abteilung für Systematik*, show that this transmission of qualities from their possessor to his descendants really occurs.

It is by no means every individual that undergoes a change through the influence of unaccustomed external influences. Several preserve the parental aspect. And as the parental characteristics were not from the beginning such as they are at present, but are, as is shown by experiment, the result of certain conditions, the transmission

to the descendant of these parental characteristics which have also been acquired is the clearest proof of the heredity of acquired characteristics.

In spite of all his objections to the theoretical part of Eimer's work, Minot allows that the 'Butterflies' are "valuable from the standpoint of the systematic entomologist, since his groups are natural ones and his grouping of the species is in the main correct."

In his grouping of the butterfly species Eimer was guided by those laws which his study of the markings of other groups of animals had caused him to regard as the general rule, and which he therefore considers himself entitled to apply hypothetically to butterflies. The grouping of species being admitted by Minot to be natural, this is sufficient proof of the correctness of those theories which this grouping presupposes. In designating those groups as natural ones in which longitudinally striped forms develop into spotted, transversely striped and unicolored ones, Minot acknowledges the law of evolution of markings in its full significance.

Darwin, himself, in his 'Origin of Species,' employs similar proofs to show that the same groups of pigeons are descendants of *Columba livia*. Their phylogenetic connection is to him proved by the fact of elements of the markings of *Columba livia* appearing in the plumage of our tame pigeons.

The ontogenetic development of those groups of animals the markings of which Eimer has studied is to him a valuable argument for the correctness of the law laid down for their phylogenesis. Similar investigations made by E. Haase on the evolution of the markings on the wings of the chrysalis of *Papilio Podalirius*, in so far as his limited materials permitted decisive conclusions, completely confirm Eimer's assertions.

These and other researches on the same subject led me to make similar investigations, the results of which I am about to publish. They furnish the best proofs for the laws found by Eimer. My specimens showed that not only single characteristics develop in the way described by Eimer, but that the markings of *Papilio Podalirius* or *Machaon*, as a whole, undergo an evolution in which the degrees of *Alebion*, *Glycerion* or the *Turnus* group are clearly distinguishable.

It would be of great interest to investigate the American forms of *Papilio* in order to see whether Eimer's 'bold hypotheses,' as Minot calls them, apply here. On the basis of arguments which have hitherto been considered customary and convincing in biology, I believe I have shown that Eimer far from rejecting Darwin's theory as a whole, because 'it does not explain the origin of variations.' He knows as well as Minot that Darwin does not even attempt an explanation of their origin. As, however, the theory of the origin of species demands an explanation of the origin of new characters, Darwin has not, as Eimer shows, explained that which he wished to explain. Eimer, on the contrary, shows in the 'Butterflies' how new qualities develop; he explains the causes of their formation and traces the laws of their development. This necessarily led to his well founded theory of the origin of species by means of variations and their propagation. The arguments contained in the 'Butterflies' must convince anybody who examines them somewhat more closely than Minot, that, as Eimer shows, variations and, therefore, the origin of species do not take place arbitrarily in the most varied, but according to Orthogenesis in a few absolutely definite, directions, not influenced by any sort of natural selection and without any reference to teleology. Eimer's theory of orthogenesis, proved as it is by facts, certainly negatives the function of

natural selection as a transforming factor, but acknowledges its preserving and intensifying power. This is the only concession that can be made to the theory of natural selection as long as the results of Eimer's investigations have not been refuted by facts, not, as heretofore, by words. Till then, I believe, one cannot deny to Eimer's work the appreciation contained in Minot's introductory sentences: "If Professor Eimer's claims are correct, his researches mark one of the great epochs of biological discovery."

I wish to state that this is merely a preliminary exposition of Eimer's views, intended for rectifying the erroneous judgment expressed by Minot. Eimer's work on organic evolution (Macmillan, 1889) gives a detailed account of his theoretical views and of the facts on which they are based. His work on Butterflies, which was criticised by Minot, serves to furnish further corroboration of the theory advanced in the above work on evolution. In his lecture at Leyden he has also given a complete exposition of his ideas in their relation to the theory of selection and of Weismannism; against the latter Eimer takes a most decided stand (see 'Extract from Comte Rendu des Séances du 3me Congrès international de Zoologie, Leyde, 16–21 Sept., 1895). This lecture includes the programme of Eimer's most recent exposition of 'Orthogenesis' embodied in a work that is just about to appear.

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THE Countess von Linden's article presents the arguments in favor of Eimer's theory. A reply seems unnecessary and others will judge of the value of the theory. Eimer's earlier papers I knew; whether I understood them or not I cannot decide. All of Eimer's evidence is essentially that he *asserts* that of a group of living species a certain form or certain forms are ancestral types. If one denies that assertion Eimer cannot *prove* that it is correct, but unless he *proves* it his deductions remain hypotheses. The reader is asked to consider whether Countess von Linden offers proof that a certain species in any given case is the ancestral race.

For the sake of a fair discussion I am glad that the preceding communication from Professor Eimer's assistant appears in SCIENCE.

CHARLES S. MINOT.

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*PROGRESS OF PROFESSOR KITASATO'S INSTITUTE FOR INFECTIOUS DISEASES AT TOKIO.**

AMONG the changes in the general condition of Japan, due to the introduction of Western civilization, one of the most noteworthy is the entire revolution in the system of medicine; the old Chino-Japanese school has been superseded by the scientific system of the West, and the striking feature of the new medicine in this empire is the ascendency of the bacteriological element. The center of this movement is seated at the 'Institute for Infectious Diseases,' directed by Dr. Kitasato.

To Mr. Fukusawa belongs the credit of having initiated the introduction of this branch of medical science into this country by building, at his own expense, a laboratory for Dr. Kitasato, upon the latter's return from Germany in 1892. I do not mean to ignore what has been done at the University and elsewhere; I only emphasize the great impetus that the study of the micro-organisms has enjoyed since the establishment of the above mentioned laboratory. Subsequently the Institute became connected with the 'Sanitary Society of Japan.' The ensuing year the Imperial Diet

* This article was prepared at the request of the Editors. Dr. Nakagawa is a graduate of Princeton University.